CDMA BUNCHED SYSTEMS FOR IMPROVING FAIRNESS PERFORMANCE OF THE PACKET DATA SERVICES

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Abstract – In this paper, bunched system is proposed for improving fairness performance of CDMA packet data systems. The fairness and throughput performance of bunched system are evaluated and compared with those of conventional cellular system. Broadcasting and selecting schemes are applied as the transmission scheme on downlink in bunched system. We develop a model of received E_b / N_o in bunched system. The system performance measures include fairness performance factor and cell throughput. A computer simulation is developed and used. The derived results show that both fairness and throughput performance are improved by bunched system in macro- and micro-cellular environments. It is also shown that selecting scheme outperforms broadcasting scheme. From the results, it is confirmed that bunched system can improve the fairness of service quality as well as system throughput.

I. INTRODUCTION

In the next generation mobile communication systems, efficient control schemes are required for the packet data transmission on downlink. Unlike voice service, most data services allow different quality of service (QoS) levels within a certain range. However, a wide difference of QoS among users can result in unfairness.

On downlink, it is not easy to achieve all the objectives including maximum throughput and fair QoS over the whole service area. If more radio resources are assigned to users with higher C/I, system throughput can be increased but fairness performance will be degraded. On the contrary, if more resources are assigned to users with lower C/I for fairness, overall system throughput will be decreased. Airy and Rohani [1] showed this tradeoff between fairness and throughput. In other studies [2, 3], various scheduling algorithms for controlling the degree of fairness have been investigated. However, both fairness and throughput can not be improved simultaneously by using only scheduling algorithm.

This paper proposes bunched system for improving fairness performance of CDMA packet data systems, while not reducing system throughput. It is well known that bunched system, in other words, distributed antenna system, has an advantage of reducing pathloss between base station (BS) and mobile station (MS). So far many researches on bunched system have focused on the voice and low data-rate services [4, 5]. We apply bunched system for the purpose of improving the downlink performance of packet data systems, and also compare its performance with that of conventional cellular system.

This paper is organized as follows: Section II describes the system model including the transmission schemes, received E_b / N_o model and performance measures. In section III, the simulation model used for performance evaluation is given. The simulation results are also shown and discussed. Finally, conclusions are drawn in section IV.

II. SYSTEM MODEL

A. Transmission Schemes on Downlink

Bunched system consists of a CU (Central Unit) and multiple RAUs (Remote Antenna Unit). It is easy to extend or change the service area in the urban and indoor environment just by adding or relocating RAUs. In addition, pathloss of radio link can be reduced, which leads to smaller transmission power and a reduced overall interference. Compared to conventional system, bunched system has a flexibility in organizing radio network, and can also improve the system performance by reducing interference.

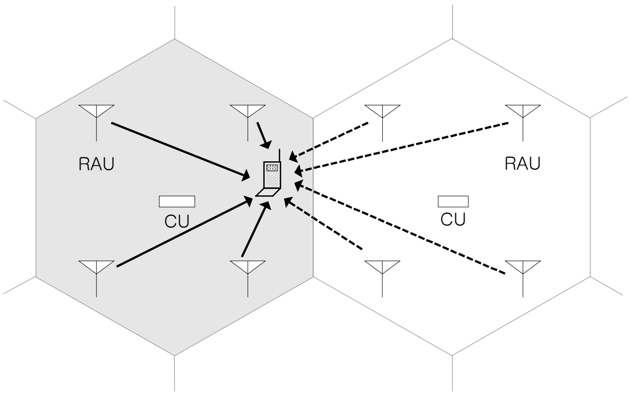
Two transmission schemes on downlink are applied in bunched system. One is the broadcasting scheme that broadcasts same signal through all RAUs. The other is the selecting scheme that transmits signals through selected one or multiple RAUs close to user. Selecting scheme can reduce overall interference more than broadcasting scheme. The two transmission schemes are illustrated in Fig. 1.

We apply the simple power allocation scheme such that the BS power is equally divided among packet data users receiving simultaneously.

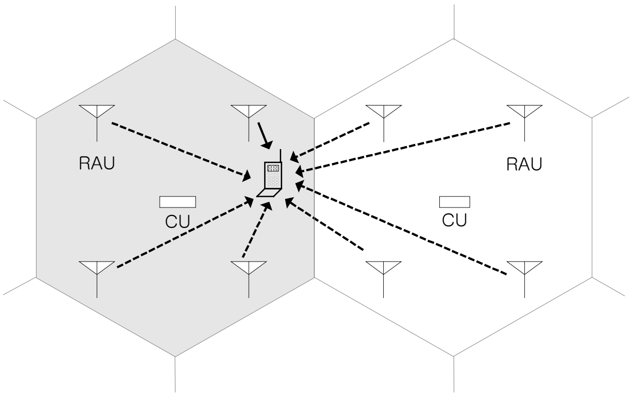
Power allocated to i_{th} MS at k_{th} RAU of j_{th} CU can be represented as

$$P_{i,(k,j)} = \frac{P_{(k,j),max}}{N_u} \tag{1}$$

where $P_{(k,j),max}$ is the maximum transmission power of k_{th} RAU of j_{th} CU and N_u is the number of data users receiving simultaneously.



a) Received signals in broadcasting scheme



b) Received signals in selecting scheme

——— Received signal from connected RAU

- - - - Received signal from other RAU

Fig. 1. Transmission scheme in bunched system

The rate control scheme is applied for packet data services. The assigned data rate to a user is dependent on the received C/I. The highest data rate is assigned to each user as long as the received E_b / N_o is larger than the required E_b / N_o for target frame error rate (FER). The rate control scheme for delay-tolerant services can increase the system throughput [6].

B. Received E_b / N_o Model

We develop the received E_b / N_o model that can be applied to bunched system.

In conventional cellular system, the received E_b / N_o on downlink can be represented as

$$\left(\frac{E_b}{N_o}\right)_{i,j} = \frac{P_{i,j} / L(d_{i,j})}{Isc + Ioc + N_o W} \cdot \frac{W}{R_i} \tag{2}$$

where i and j are indices of MS and BS, respectively. $P_{i,j}$ is the power allocated to i_{th} MS at j_{th} BS and W is spreading bandwidth. R_i is the assigned data rate to i_{th} MS and $N_o W$ is thermal noise power. $L(d_{i,j})$ and $d_{i,j}$ are pathloss and distance between j_{th} BS and i_{th} MS, respectively. Pathloss model selected for this study is

$$L(d_{i,j}) = \begin{cases} L_0 - 10\mu_1 \log(d_{i,j}) & 1 < d_{i,j} < D_B \\ L_0 - 10\mu_2 \log(D_B) - 10\mu_2 \log(\frac{d_{i,j}}{D_B}) & d_{i,j} \geq D_B \end{cases} \tag{3}$$

where μ_1 and μ_2 are pathloss exponents before and after breakpoint, respectively. L_0 is pathloss at 1m distant from BS. D_B is distance from BS to breakpoint. Shadowing is assumed as lognormally distributed with zero mean and standard deviation σ.

Downlink interference consists of the same cell interference (*Isc*) and other cell interference (*Ioc*). *Isc* is the interference of other signals that are received from the connected BS. *Ioc* is the interference from other BSs.

$$Isc = (1-\rho)(P_j - P_{i,j}) / L(d_{i,j}) \tag{4}$$

$$Ioc = \sum_{k \neq j}^{Number\ of\ BS} P_k / L(d_{i,k}) \tag{5}$$

where ρ is the orthogonality factor.

In bunched system, the received E_b / N_o can be represented as

$$\left(\frac{E_b}{N_o}\right)_{i,j} = \sum_{k=0}^{N} \left(\frac{P_{i,(k,j)} / L(d_{i,(k,j)})}{Isc,sr + Isc,or + Ioc + NoW} \cdot \frac{W}{R_i} \right) \tag{6}$$

where i, k and j are indices of MS, RAU and CU, respectively. In broadcasting scheme, N is the number of all RAUs within a bunch. In selecting scheme, N is the number of the connected RAUs. *Isc,sr* is the interference from the connected RAU within a bunch. *Isc,or* is the interference from other RAUs within a bunch. *Ioc* is the interference from other BSs.

$$Isc,sr = (1-\rho_{sr})\left(P_{(k,j)} - P_{i,(k,j)}\right)/ L(d_{i,(k,j)}) \quad (7)$$

$$Isc,or = (1-\rho_{or})\sum_{t \neq k}^{K} P_{(t,j)} / L\left(d_{i,(t,j)}\right) \quad (8)$$

$$Ioc = \sum_{m \neq j}^{M} \sum_{k=1}^{K} P_{(k,m)} / L\left(d_{i,(k,m)}\right) \quad (9)$$

where $P_{(k,j)}$ is the total transmission power of k_{th} RAU of j_{th} CU. M and K are the number of CU and RAU, respectively.

The received signals from other RAUs along multi paths can be less orthogonal to the desired signal than those from the connected RAU. This difference of orthogonality is considered in (7) and (8). ρ_{sr} is the orthogonality factor between the desired signal and other signals from the connected RAU. ρ_{or} is the orthogonality factor between the desired signal and other signals from other RAUs.

The maximal ratio combining scheme utilizing macro diversity between RAUs is applied for improving the received E_b / N_o. An ideal maximal ratio combining is assumed in (6).

C. Fairness and Throughput

Fairness performance can be measured by the difference of QoS provided to users. We define fairness performance factor $F_{mean/STD}$ as

$$F_{mean/STD} = 10\log\left(\frac{\mu_u}{\sigma_u}\right) \quad (10)$$

where μ_u and σ_u are the mean and the standard deviation of assigned data rate to users, respectively. As $F_{mean/STD}$ gets lower, the distribution of user data rate becomes wider, which means deterioration of fairness.

Cell throughput is defined as the sum of effective data rates provided by a BS and can be represented as

$$Cell\ Throughput = \sum_{i=1}^{N_u} R_i\left[1 - FER\left(E_b / N_o\right)_i\right] \quad (11)$$

where R_i is the assigned data rate to i_{th} MS and $(E_b / N_o)_i$ is the received E_b / N_o of i_{th} MS. The subscript *j* for BS is dropped for convenience.

$FER(E_b / N_o)_i$ is the actual FER corresponding to $(E_b / N_o)_i$. Even though rate control scheme is applied, $(E_b / N_o)_i$ is higher than or equal to required E_b / N_o due to the discontinuity of allowable data rate. In this case, actual FER should be lower than or equal to target FER. We obtain the relationship between actual FER and $(E_b / N_o)_i$ from link level simulation, and then utilize it to derive cell throughput in (11).

III. PERFORMANCE OF BUNCHED SYSTEM

The downlink performances of bunched system are evaluated by using a computer simulation in macro- and micro-cellular environments. The derived results are also compared with those of conventional cellular systems.

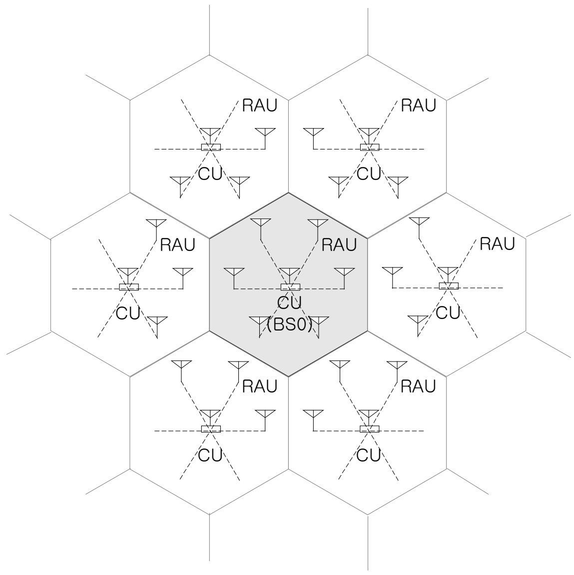


Fig. 2. Deployment model in macrocell environment

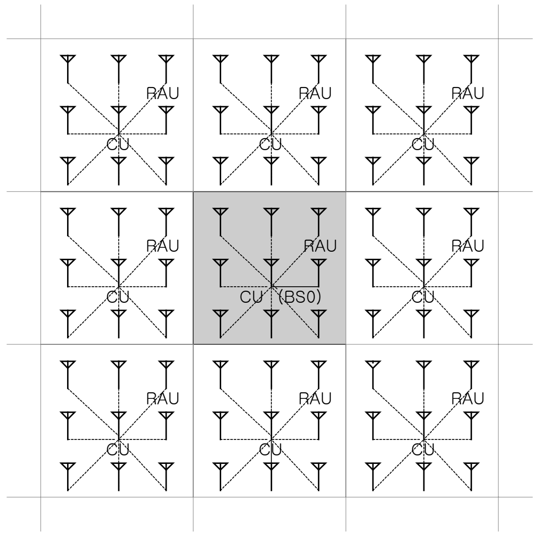


Fig. 3. Deployment model in microcell environment

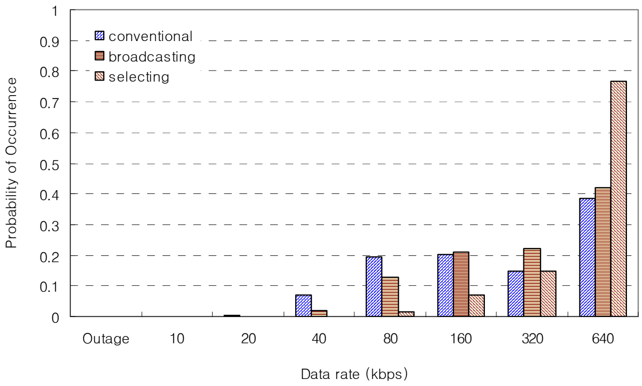


Fig. 4. The distribution of assigned data rate in microcell

The deployment models of a CU and RAUs in macrocell and microcell are shown in Fig. 2. and 3, respectively. The system parameters and the default values set for the analysis and are listed in Table 1.

Fig. 4 shows the distribution of the data rates assigned to a user in microcell. Three different cases are compared in the figure: conventional system, bunched system with broadcasting scheme and bunched system with selecting scheme. Results show that bunched system can provide higher data rate than conventional system, and the data rate with selecting scheme is the highest among the three cases. In particular, selecting scheme can provide 640kbps data rate to over 75% of users. From the figure, it is found that the assigned data rate can be increased by introducing bunched system.

Table 1. Simulation Parameters

Parameters	Values	
	Macrocell	Microcell
Cell layout	Hexagonal	Rectangular
Cell radius	1km	300m(width)
Number of RAU / Cell	7	9
Chip rate (Mcps)	3.84	
Shadowing Standard dev. (dB)	8	10
ρ_{sr} / ρ_{or}	0.6 / 0.3	0.94 / 0.5
Overhead CH power ratio	0.15	
Antenna gain (dBi)	15	
μ_1 / μ_2	2 / 4	
Data rate set (kbps)	{10,20,40,80,160,320, 640}	

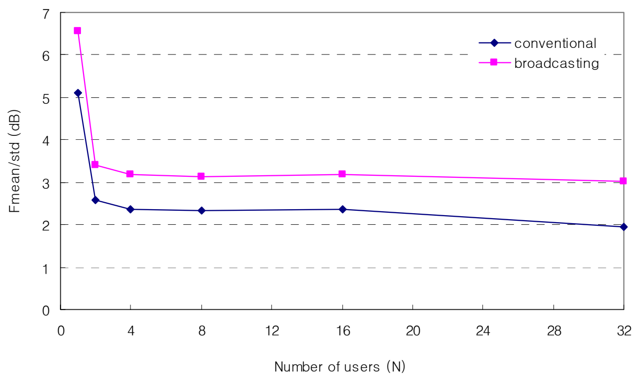


Fig. 5. Fairness in macrocell

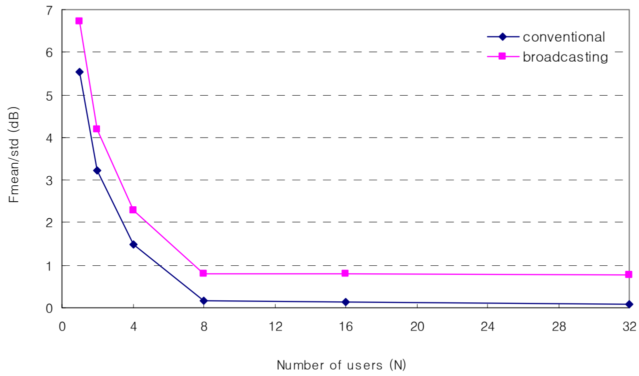


Fig. 6. Fairness in microcell

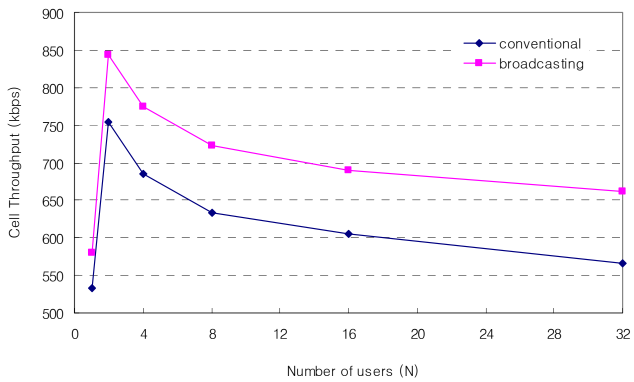


Fig. 7. Cell throughput in macrocell

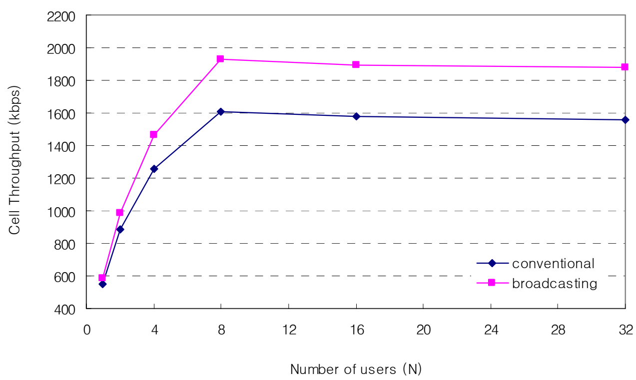


Fig. 8. Cell throughput in microcell

The fairness performance and system throughput are evaluated in conventional and bunched systems.

Fig. 5 and 6 show the fairness performance with varying number of data users receiving simultaneously N_u. The fairness performance factor is derived in macro- and micro-cellular environments. It can be seen that $F_{mean/STD}$ is increased by about 1dB in both macrcell and microcell, and this increment is almost independent of N_u. It is confirmed that the fairness performance can be improved by bunched system.

Fig. 7 and 8 show the cell throughputs of conventional and bunched system. It is shown that the cell throughput can also be increased by bunched system. From the results in the figure above, it is found that bunched system can improve fairness performance while not reducing but increasing cell throughput. Fig. 7 and 8 also show that cell throughput in macrocell is more reduced than in microcell as N_u increases. It is because lower orthogonality in macrocell leads to more interference from the connected BS.

Table 2 shows the fairness performance of bunched system by broadcasting and selecting schemes in micro-cellular environment. In this case, the selecting scheme transmits through only one RAU.

From the results, it is found that selecting scheme increases μ_u and decreases σ_u compared with broadcasting scheme. It can be seen that $F_{mean/STD}$ is also improved by about 3.5dB when selecting scheme is applied. The total interference from the connected BS as well as other BSs is reduced extremely by one RAU selection. It is found that selecting scheme outperforms broadcasting scheme in both fairness and throughput.

Table 2. Fairness in bunched system

	μ_u	σ_u	$F_{mean/STD}$
Broadcasting	366 kbps	216 kbps	2.28 dB
Selecting	543 kbps	166 kbps	5.16 dB

IV. CONCLUSIONS

We have proposed the CDMA bunched system for improving fairness performance of the packet data services and showed the fairness and throughput performance on downlink.

The fairness and cell throughput performance of bunched system are evaluated, which are compared with those of conventional system. The simulation results show that fairness performance is improved by introducing bunched system in both macro- and micro-cellular environments. Moreover, unlike scheduling schemes that are typically used for improving the fairness performance, bunched system can improve both fairness and cell throughput simultaneously.

Broadcasting scheme and selecting scheme are applied as transmission schemes in bunched system. The performance results of two schemes show that selecting scheme outperforms broadcasting scheme in both fairness and throughput. From the overall results, it is confirmed that bunched system with selecting scheme can be applied as one of schemes to improve the fairness of service quality as well as system throughput.

The system model and analyzed results presented in this paper can be utilized to design and develop radio access network for the high speed packet data services.

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